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A1_1 The Power of Love

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Abstract

We modelled the power output of a small hydroelectric turbine placed within the descending aorta of a human and plotted this against the age of the individual. We found that the optimal age for energy generation with this model ranges from roughly 62 to 74 years old for a power output range of approximately 1.2 W to 2.9 W, although we suggest that less dangerous methods of power generation are preferable.

Introduction

With a power output of roughly 1 W [1], the heart is a key organ within the body. Blood is then pumped from the heart through the aorta. If this process could be exploited for energy in a similar fashion to hydroelectric power, what power output would we expect, and how would this power output vary with the age of the individual?

Theory

The hydroelectric turbine would be placed at the bottom of the descending aorta, with the blade filling the entire diameter. The power output (in W) of a hydroelectric turbine is given by:

$$P = \eta \rho Q g h. \tag{1}$$

Where η is efficiency (assumed to be 0.9 [2]), ρ is the density of blood (1060 kg m^{-3} [3]), Q is the volume flow rate of blood through the aorta in m^3 s^{-1}, g is acceleration due to gravity ($g = 9.81$ m s^{-2}), and h is the length of the aorta [4].

The volume flow rate, Q, is given by:

$$Q = v\pi(d/2)^2. \tag{2}$$

Where v is the velocity of blood through the descending aorta in m s^{-1} and d is the diameter of the descending aorta. Substituting equation (2) into equation (1) gives us:

$$P = \eta \rho v \pi g h (d/2)^2. \tag{3}$$

While assuming ρ and g are constants, previous studies have shown that the values of v, d, and h vary with age. C. T. Dotter et al. [5], found that h in cm varies with age according to:

$$h = (6.76 + 15.86 \log_{10} N \pm 5.07). \tag{4}$$

Where N is the age of the individual in years. Similarly, M. Hannuksela et al. [6], found that the upper limit for the diameter d of the descending aorta in mm increases with age by:

$$d = (21 + 0.16N). \tag{5}$$

We assumed a -5 mm difference to the lower limit. Finally, A. Salmasi and C. Doré [7] found the velocity of blood through the heart decreases by approximately 1% per year from ages 20 to 70, and thus we made a conservative estimate of an approximate decrease of 70% between ages 0 and

100 from a maximum peak velocity of roughly 1.6 ± 0.2 m s^{-1} [7], giving:

$$v = (1.6 \pm 0.2) - (0.7 \times (1.6 \pm 0.2) \times 0.01N). \quad (6)$$

Results

Substituting equations (4), (5), and (6) into equation (3) for a range of N from 0 to 100 produced the plot found in Figure 1.

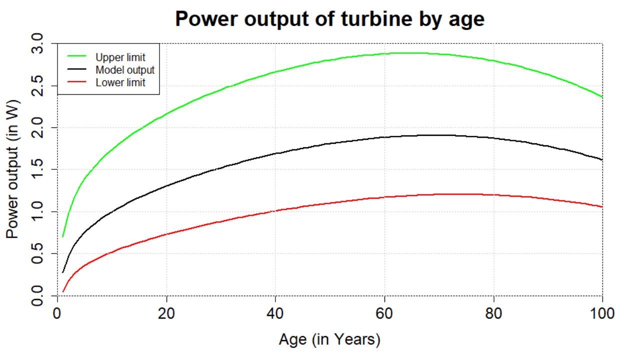

Figure 1: R Plot showing how the power output of the turbine varies with age, with the upper limit assuming maximum positive uncertainties and the lower limit assuming maximum negative uncertainties. The peak output ranges from approximately 1.2 W to 2.9 W for an optimal age range of roughly 62 to 74 years old.

Discussion and Conclusion

The energy range generated is far greater than the 1 mW generated using hydroelectric turbines in peripheral arteries suggested by A. Pfenniger et. al. [8]. The age range of roughly 62 to 74 years old for maximum power output is also surprising, as it was anticipated that a younger person would be able to generate more power with such a device. We suspect that if we were to consider more effects of aging on the circulatory system other than just aortic dimensions and blood velocity, the age of maximum power output would decrease.

There are also factors other than age that may affect the power output of the device that we have not considered. For example, BMI can also influence the diameter of the descending aorta [6].

There is also an issue with the viability of this device. Our proposed positioning would lead to the turbine blocking the entire diameter of the descending aorta. Considering this is the main artery blood travels through after leaving the heart, any amount of blockage could easily endanger the individual's life.

In conclusion, the aortic hydroelectric turbine has an peak power output range of roughly 1.2 W to 2.9 W from ages 62 to 74 years. This power output is not insignificant, but less dangerous ways of acquiring power using the body, such as using less vital arteries [8] or temperature gradients within the body [9], are a preferable alternative to potentially throttling one of the most vital arteries we have.

References

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